Temporal Trends in Identification, Management and Clinical Outcomes Following Out-of-Hospital Cardiac Arrest: Insights from the Myocardial Ischaemia National Audit Project Database

Tiffany Patterson[1] PhD MRCP, Gavin D Perkins[2] MD FRCP FFICM FERC, Yahma Hassan[1] MBBS, Konstantinos Moschonas[3] MBBCh MRes, Huon Gray[4] MD FRCP FESC FACC, Nick Curzen[4] BM PhD FRCP, Mark de Belder[5] MA MD, Jerry P. Nolan[6] FRCA FRCP FCEM FFICM, Peter Ludman[7] MA MD FRCP FESC, Simon R Redwood[1] MD FRCP FACC FSCAI

1. Cardiovascular Division, The Rayne Institute BHF Centre of Research Excellence, King's College London, St. Thomas' Hospital, London, UK
2. Warwick Clinical Trials Unit and Heart of England NHS Foundation Trust, Warwick Medical School, University of Warwick, Coventry, UK
3. King's College Hospital, London, UK
4. Wessex Cardiothoracic Centre, University Hospital Southampton NHS Foundation Trust & Faculty of Medicine, University of Southampton, UK
5. Cardiology Department, The James Cook University Hospital, Middlesbrough, UK
6. School of Clinical Sciences, University of Bristol and Department of Anaesthesia, Royal United Hospital, Bath, UK
7. Cardiology Department, University Hospitals Birmingham NHS Foundation Trust, UK

Short Title: Trends in Outcomes Following OHCA

Corresponding Author:
Simon R Redwood, Professor of Interventional Cardiology
Cardiovascular Department, Kings College London
St Thomas' Hospital, London SE1 7EH
Email: simon.redwood@gstt.nhs.uk
Tel: +44 (0) 207 188 1083

Disclosure: The authors have no disclosures or conflicts of interest to share
Keywords: Out-of-hospital Cardiac Arrest, Coronary angiography, Percutaneous Coronary Intervention
Total Word Count: 4979

Acknowledgements

We are grateful to the MINAP Academic Group for allowing access to the MINAP database.

Background

There is wide variation in survival rates from out-of-hospital cardiac arrest (OHCA) and overall survival remains poor. There is expert consensus that early reperfusion therapy in ST-elevation (STE) reduces mortality. The management of patients without STE however is controversial.

Methods

The MINAP database is a national registry of all hospital admissions in England and Wales treated as acute coronary syndrome (ACS). We examined temporal trends, over a 5-year period, of OHCAs identified by the Myocardial Ischaemia National Audit Project (MINAP) registry, admitted to hospital and treated as ACS, the interventional management of these patients and clinical outcomes.

Results

410,462 patients were admitted to hospital in England and Wales with ACS. Of these, 9,421 presented with OHCA (2.30%). There was an increase in OHCA cases as a proportion of ACS between 2009 and 2013 (2.74% in 2013 versus 1.79% in 2009; $P_{trend}<0.001$). The rate of coronary angiography + percutaneous coronary intervention (CA+PCI) increased in ACS patients presenting with OHCA (66.3% in 2013 (884/1,334) versus 54.9% in 2009 (876/1,595); $P_{trend}<0.001$). Time-varying cox-proportional hazards model demonstrated CA±PCI (in patients with and without STE) was associated with reduced mortality before (HR=0.35, 95% CI: 0.20 to 0.60; $P<0.05$) and after (HR=0.36, 95% CI: 0.25 to 0.50; $P<0.001$) 30 days. Predictors of favourable outcome were synonymous with the selection criteria for patients undergoing CA±PCI.

Conclusions

This observational study showed that selection for CA±PCI was associated with reduced mortality in OHCA patients diagnosed with ACS. These data support the need for a randomized controlled trial.

Background

Out-of-hospital cardiac arrest (OHCA) is a global public health issue. Each year there are approximately 28,000 emergency medical services (EMS)–treated OHCA in England and approximately 330,000 EMS-attended OHCA in the United States.[1,2] There is wide variation in survival rates from OHCA and overall survival remains poor, with a reported average of 7%.[1] The adoption of systematic approaches to cardiopulmonary resuscitation may improve long term survival from OHCA.[3,4] Post-resuscitation care in-hospital including targeted temperature management and treatment of the underlying cause through coronary reperfusion is thought to further improve this survival in patients with acute coronary syndromes (ACS).[5] It is difficult to conclude which of the components of post-arrest care is essential, given the observational nature of studies. Coronary artery disease is responsible for > 70% of OHCA of presumed cardiac cause, with an acute occlusion demonstrated in 50% of consecutive patients taken immediately to coronary angiography.[6] There is expert consensus that early reperfusion therapy in ST-elevation (STE) reduces mortality.[7,8] The management of patients without STE however is controversial, with an emphasis placed on prior rule out of non-coronary causes.[8] Randomized data are lacking and the benefit of early reperfusion therapy remains debated. This has led to a variable uptake of such a strategy amongst the interventional cardiology community. The Myocardial Ischaemia National Audit Project (MINAP) database is a non-commercially funded national registry of all hospital admissions treated as ACS in England and Wales, established to examine the quality of management of hospitals providing acute cardiac care.[9] The strengths of this registry include its size and national reach. This database selectively captures OHCAs that are admitted to hospital with a final diagnosis of ACS and does not encompass all OHCA admissions to hospital. Therefore the aim of this study was to examine the temporal trends, over a 5-year period, of OHCAs identified by the MINAP registry, admitted to hospital and treated as ACS, the interventional management of these patients and clinical outcomes.

Methods

The MINAP registry consists of 123 core data-points, including cardiovascular risk factors, occurrence of cardiac arrest, post-resuscitation therapies including coronary angiography and PCI, and outcomes including in-hospital mortality and neurological outcome; these data-points have been published previously.[10] Of the 123 separate fields, 49 data sets were extracted and examined (Section 1, Supplementary Material). These clinical audit data are a valuable resource and missing values are inevitable when large volumes of data are collected and have the potential to bias or reduce the efficiency of statistical estimators if they are not treated appropriately. Thus we performed multiple imputations to deal with these missing data. Patients are identified at individual hospital level and data entry, performed by trained personnel, undergoes annual validation through re-audit. MINAP has approval from the Patient Information Advisory Group to use patient identifiable information without individual patient consent. MINAP approved this current registry-based project and data analyses were performed at King's College London, St Thomas' Hospital, UK with the support of London School of Hygiene and Tropical Medicine Clinical Trials Unit, UK.

Study Population and Outcomes Reported

For the purposes of this study, fully anonymized data were retrospectively extracted from the MINAP dataset of hospitals in England and Wales accepting admissions between January 2009 and July 2013. ACS was categorized as ST-Elevation myocardial infarction (STEMI) or Non-STEMI based on biomarker and electrocardiographic criteria. OHCA was defined as cardiac arrest before arrival at hospital. Procedural intervention was classed as no coronary angiogram, coronary angiogram alone and coronary angiogram + PCI. In-hospital mortality is defined as patient death in-hospital. Life status is tracked by MINAP through linkage with the Office of National Statistics using the unique National Health Service identifier (number), thus represents in-hospital mortality and subsequent mortality following discharge.

Statistical Analysis

Categorical data were presented as counts and percentages, and comparison between groups performed using chi-square test; numerical data were presented as mean ± SD, and analysis performed using one-way ANOVA. The temporal trends in identification of OHCA, followed by distribution of baseline characteristics (male gender, presence of STE, previous MI, previous angina, hypertension, hypercholesterolemia, peripheral vascular disease, cerebrovascular disease, chronic renal failure, heart failure, smoking history, diabetes, previous PCI, previous coronary artery bypass graft surgery (CABG), family history, presenting rhythm of pulseless ventricular tachycardia/ventricular fibrillation (VT/VF) and age>75), the rate of procedural intervention, in-hospital mortality and good neurological outcome (defined as cerebral performance category 1 or 2 at discharge) of the ACS cohort presenting with OHCA were examined. For trend analysis year-on-year we used the Cochran-Armitage test for trend to test for linear relationships between categorical variables. To determine independent predictors for in-hospital mortality and the odds of undergoing procedural intervention (CA±PCI), multivariable adjusted logistic regression models were used to generate odds ratios. To limit the number of variables for the final multivariable models, stepwise regression was performed using the above covariates (entry criteria $P<0.05$, exit criteria $P>0.1$); significant variables were used in the final model. Final model selection was performed using multiple imputation (Fully Conditional Specification, SPSS v24.0 (IBM Corp.©)) to impute missing data on baseline covariates by chained equations to create 5 multiply imputed datasets to maximise statistical power (missing values and multiple imputation methodology is reported in Section 2, Supplementary material). The variables used in the final model of the odds of undergoing CA±PCI were: gender, STE, previous MI, previous angina, hypertension, hypercholesterolemia, peripheral vascular disease, cerebrovascular disease, chronic renal failure, heart failure, smoking history, diabetes, previous PCI, previous CABG, family history, VT/VF and age>75. The variables used in the final model for in-hospital mortality were as for the previous model with the addition of CA±PCI. No significant co-linearity was demonstrated. Due to the large proportion of missing data, complete case analysis was performed in parallel, these results were compared with those of multiply imputed data to increase the robustness of our conclusions (Section 3, Supplementary material). Time to event analysis was performed using Kaplan-Meier curves, Cox proportional hazard analyses model was performed to generate (i) time-varying hazard ratio for <30 days and >30 days and (ii) time-varying exposure to coronary angiography (to account for survival bias) using time-varying covariate of transition time to coronary angiogram. All p values were two-sided with a significance threshold $P<0.05$. Statistical analysis was performed using SPSS v24.0 (IBM Corp.©).

Results

Trends in Incidence of ACS Presenting as OHCA

Figure 1 details case identification. From January 2009 to July 2013 we identified 410,462 patients admitted to hospital in England and Wales with a final discharge diagnosis of troponin positive ACS. Over the 5-year period, 385,509 did not experience cardiac arrest and 24,953 experienced cardiac arrest. Of the 24,953 cardiac arrest patients, 9,421 of these patients were identified as out-of-hospital cardiac arrest (OHCA). The overall proportion of ACS patients presenting with OHCA (9,421) relative to the overall cohort of patients diagnosed with ACS (410,462) was 2.3%. This proportion increased yearly from 2009 to 2013 (1.8% (1,595/89,380) in 2009, 2.0% (1,835/91,087) in 2010, 2.4% (2,142/90,559) in 2011, 2.8% (2,515/90,705) in 2012 to 2.7% (1,334/48,731) in 2013; P_{trend}<0.001), Section 4, Supplementary material.

Baseline Characteristics of Identified Cases of OHCA

Table 1 depicts the changes in baseline demographics from 2009 to 2013 of the study cohort under question of patients identified in-hospital with a discharge diagnosis of ACS who presented with OHCA (n=9,421) (Figure 1). In the overall cohort of ACS patients presenting with OHCA, the prevalence of known underlying ischemic heart disease (previous angina (20.4% (326/1595) in 2009 versus 15.8% (211/1334) in 2013; P_{trend}<0.001), previous acute myocardial infarction (21.8% (348/1595) in 2009 versus 17.4% (232/1334) in 2013; P_{trend}<0.05) and previous CABG (7.3% (116/1595) in 2009 versus 5.5% (73/1334) in 2013; P_{trend}<0.05) and risk factors for coronary artery disease (hypercholesterolemia (28.8% (459/1595) in 2009 versus 25.0% (333/1334) in 2013; P_{trend}<0.05), smoking history (64.5% (1028/1595) in 2009 versus 60.6% (809/1334) in 2013; P_{trend}<0.05) and positive family history (25.5% (407/1595) in 2009 versus 23.1% (308/1334) in 2013; P_{trend}<0.001)) significantly decreased. There was no significant change in patients presenting with pulseless VT/VF (88.9% (1418/1595) in 2009 versus 86.9% (1159/1334) in 2013; P_{trend}=0.06) (Section 4, Supplementary Material). An increase in male gender (74.8% (1193/1595) in 2009 versus 77.7% (1037/1334) in 2013; P_{trend}<0.05) and STE on the post-resuscitation ECG (62.6% (999/1595) versus in 2009 versus 65.4% (872/1334) in 2013; P_{trend}<0.05) was seen. In this overall cohort of 9,421 OHCA patients identified in-hospital with a discharge diagnosis of ACS, male gender (75.9%, 7,148/9,421) with presenting rhythm of VT/VF (88.2%, 8,313/9,421) and ST elevation (STE) on the post-resuscitation ECG (65.0%, 6124/9,421) predominated.

Trends in Coronary Angiography in Identified Cases of OHCA

Of the 9,421 patients identified in-hospital with a discharge diagnosis of ACS that presented with OHCA: 18.0% (1,699/9,421) did not undergo a coronary procedure; 20.8% (1,964/9,421) underwent coronary angiography (CA) alone and 61.1% (5,758/9,421) underwent CA+PCI. Within this OHCA cohort of ACS patients, over the 5-year period, CA+PCI increased from 54.9% (876/1,595) in 2009 to 66.3% (884/1,334) in 2013 (P_{trend}<0.001); conversely, CA alone decreased from 22.0% (351/1,595) in 2009 to 20.0% (267/1,334) in 2013 (P_{trend}<0.001) and the proportion of patients who did not undergo coronary procedure also decreased from 23.1% (368/1,595) in 2009 to 13.7% (183/1,344) in 2013 (P_{trend}<0.001) (annual trends are available in (Section 5, Supplementary Material). The median number of days to angiogram was 0.3 days (IQR 0 to 1.3 days) and the maximum time to angiogram was 365 days. Of the overall cohort of ACS patients presenting with OHCA, 9.4% (882/9,421) of patients died prior to coronary angiography.

We then examined the temporal trends in baseline characteristics of patients selected to undergo CA±PCI within the OHCA subgroup of ACS patients (CA±PCI; 7,722/9,421) over the 5-year period (Table 2). From 2009 to 2013, in the cohort of patients documented as having undergone CA±PCI, there was a significant increase in the proportion of male patients (76.0% (933/1,227) in 2009 versus 79.1% in 2013 (910/1,151); P_{trend}<0.05) undergoing CA±PCI. There was a significant decrease in the prevalence of cardiovascular risk factors in this cohort: including a family history of cardiovascular disease (27.8% in 2009 (341/1,227) versus 24.7% in 2013 (284/1,151); P_{trend}<0.001); previous myocardial infarction (19.7% (242/1,227) in 2009 versus 16.0% (184/1,151) in 2013; P_{trend}<0.05); history of angina (18.6% (228/1,227) in 2009 versus 14.7% (169/1,151) in 2013; P_{trend}<0.05); hypercholesterolemia (29.3% (360/1,227) in 2009 versus 25.1% (289/1,151) in 2013; P_{trend}<0.05) and smoking history (65.4% (803/1,227) in 2009 versus 61.6% (709/1,151) in 2013; P_{trend}<0.05). The proportion of patients undergoing CA±PCI with VT/VF as the presenting rhythm also decreased (91.2% (1,119/1,227) in 2009 versus 89.5% (1,030/1,151) in 2013; P_{trend}<0.05). From the 5-year cohort of ACS patients presenting with OHCA (9,421), an overall comparison of baseline characteristics was made between the groups of patients selected to undergo CA alone

(1,964/9,421), CA+PCI (5,758/9,421) and patients who did not undergo a coronary angiogram (1,699/9,421); these are presented in Table 3.

Multivariable logistic regression analysis of the patients identified in-hospital with a discharge diagnosis of ACS who presented with OHCA (n=9,421) was performed to determine the odds of undergoing (i) CA±PCI and (ii) CA+PCI in this cohort, Table 4. If STE was present, there was an eight fold increased probability of receiving CA+PCI (adjusted OR 8.34, 95% CI 7.00 to 9.94; P <0.05). A presenting rhythm of VT/VF (adjusted OR 2.16, 95% CI 1.29 to 3.63; P <0.05) or previous PCI (adjusted OR 1.88, 95% CI 1.24 to 2.85; P <0.05) was associated with a two fold increased probability of receiving CA+PCI. Patients had a significantly higher probability of receiving CA+PCI in the presence of cardiovascular risk factors including hypercholesterolemia (adjusted OR 1.31, 95% CI 1.04 to 1.66; P <0.05) and smoking history (adjusted OR 1.45, 95% CI 1.20 to 1.76; P <0.05). Conversely, those with previous coronary artery bypass grafting (adjusted OR 0.46, 95% CI 0.35 to 0.61; P <0.05) and heart failure (adjusted OR 0.69, 95% CI 0.49 to 0.98; P <0.05) were less likely to undergo a coronary procedure, Table 4.

Trends in Clinical Outcomes

Length of stay was also examined in the overall cohort of ACS patients presenting with OHCA. Median length of stay was 5 days (IQR 2 to 11) and the maximum length of stay was 388 days. In patients identified with a discharge diagnosis of ACS who presented with OHCA (n=9,421), overall in-hospital mortality was 29.2% (2,753/9,421). In patients identified with a discharge diagnosis of ACS who presented with OHCA (n=9,421), we compared clinical outcomes in patients who underwent a coronary procedure with those who did not. This was further divided into no coronary angiogram (1,699/9,421), CA alone (1,964/9,421) and CA+PCI (5,758/9,421). Overall, in patients who underwent CA+PCI, in-hospital death was significantly lower than in patients who underwent CA alone (21.8% CA+PCI 1,258/5,758, versus 37.3% CA alone, 734/1,964; *P*<0.001) and significantly lower than in patients who underwent no coronary procedure (21.8% CA+PCI, 1,258/5,758 versus 44.8% 761/1,699, no coronary procedure; P<0.001). Over the 5-year period, trend analysis demonstrated a significant increase in in-hospital mortality from 27.8% (443/1595) in 2009 to 31.0% (414/1334) in 2013 in the overall cohort of OHCA ACS patients (n=9,421).

In patients who underwent CA+PCI (n=5,758), trend analysis showed a slight but significant increase in in-hospital mortality over the 5-year period from 20.2% (177/876) in 2009 to 22.6% (200/884) in 2013 (P_{trend} <0.001). However, this increase in mortality was significantly less than the increase in mortality in the CA alone cohort (33.6% (118/351) in 2009 versus 44.3% (117/267) in 2013; P<0.001) and in patients who underwent no coronary procedure (40.2% (148/368) in 2009 versus 53% (97/183) in 2013; P<0.001).

Multivariable logistic regression analysis of the patients identified in-hospital with a discharge diagnosis of ACS who presented with OHCA was performed to determine predictors of in-hospital mortality (n=9,421). These were: older age (>75 years; OR 1.59; 95% CI 1.34 to 1.89; *P*<0.001) and the presence of pre-existing comorbidities including diabetes (OR 2.04; 95% CI 1.75 to 2.36; *P*<0.001), heart failure (OR 1.84; 95% CI 1.36 to 2.47; *P*<0.001), cerebrovascular disease (OR 1.63; 95% CI 1.29 to 2.07; *P*<0.001), chronic renal failure (OR 1.66; 95% CI 1.04 to 1.78; *P*<0.05) and peripheral vascular disease (OR 1.70; 95% CI 1.26 to 2.30; *P*<0.001) (Table 5). Conversely, the risk of in-hospital death was decreased if the patient presented with VT/VF (OR 0.21; 95% CI 0.17 to 0.26; *P*<0.001), male sex (OR 0.78; 95% CI 0.68 to 0.89; *P*<0.001) and had risk factors for coronary disease including hypercholesterolemia (OR 0.69; 95% CI 0.59 to 0.81; *P*<0.001), smoking history (OR 0.72; 95% CI 0.61 to 0.84; *P*<0.001) and family history (OR 0.37; 95% CI 0.32 to 0.44; *P*<0.001). CA+PCI was also associated with decreased risk of in-hospital mortality in the STE cohort (OR 0.58; 95% CI 0.36 to 0.96; P<0.05) but not the non-STE cohort (Table 5).

In patients identified with a discharge diagnosis of ACS who presented with OHCA we compared neurological outcomes between patients who underwent a coronary procedure with those who did not (n=9,421). This was further divided into no procedure (1,699), CA alone (1,964) and CA+PCI (5,758). In patients who underwent CA+PCI, good neurological outcome was significantly higher than in patients who underwent CA alone (61.6% CA+PCI, 3546/5758 versus 41.4% CA alone, 814/1964; *P*<0.001) and significantly higher than in patients who underwent no coronary procedure (61.6% CA+PCI, 3546/5758 versus 35.6% no procedure, 604/1,699; *P*<0.001). Trend analysis over the 5-year period showed a significant decrease in the proportion of patients with good neurological outcome in the overall OHCA

ACS cohort from 54.2% (864/1595) in 2009 to 51.3% (685/1334) in 2013 (P=0.05). In patients who underwent CA+PCI, trend analysis showed no significant change in good neurological outcome over the 5-year period from 2009 to 2013 (63.4% in 2009 (555/876) versus 61.0%% (539/884) in 2013; P_{trend} =0.07). However, in both the CA alone (45.6% (160/351) in 2009 versus 34.3% (92/268) in 2013; P<0.001) and no coronary angiogram (40.2% (148/368) in 2009 versus 29.5% (54/183) in 2013; P<0.001) cohorts, a significant decrease in good neurological outcome was seen over the 5-year period. Figure 2 demonstrates temporal trends in good neurological outcome in the overall cohort of OHCA ACS patients, those who underwent CA+PCI and the rate of coronary intervention.

In the OHCA cohort of ACS patients the association of coronary procedure with life status (survival both in-hospital and following discharge) was examined (Figure 3). Cox-proportional hazards model was used to generate time varying hazard ratios for short term and long term follow up. This demonstrated significant difference in survival between those selected to undergo any coronary procedure (CA±PCI) versus no (coronary) procedure both before 30 days (HR=0.35, 95% CI: 0.20 to 0.60; *P*<0.05) and after 30 days (HR=0.36, 95% CI: 0.25 to 0.50; *P*<0.001). This was further supported by Cox Proportional Hazards model analysis with time-varying exposure to coronary angiography (HR 0.43, 95% CI: 0.29 to 0.57; P<0.05).

Discussion

In this large, 5-year, retrospective observational study, examining patients identified in-hospital with a final diagnosis of ACS, with a specific focus on those presenting with OHCA, the main findings were as follows: 1) the proportion of ACS patients identified as presenting with OHCA increased over the 5-year period. 2) An increase in the rate of CA+PCI was demonstrated. 3) Patient selection for CA±PCI favored male patients, under 75, with STE on the post-resuscitation ECG with a presenting rhythm of VT/VF. 4) A significant increase in CA±PCI in the STE patients was seen over time. 5) Overall in-hospital mortality was significantly lower and neurological outcome better in patients selected to undergo CA+PCI from the ACS cohort presenting with OHCA (both STE and non-STE patients). 6) Over the 5-year period the rate of good neurological outcome in the CA+PCI cohort remained unchanged.

The MINAP registry was established with the intention of capturing all patients admitted to hospital, diagnosed with and treated as acute coronary syndrome. MINAP is a hospital-based ACS registry completed by Cardiology personnel, thus will not capture all patients resuscitated from cardiac arrest and admitted to hospital. As part of a focus on improving care, the Department of Health for England introduced survival from cardiac arrest as part of the Ambulance Service National Quality Indicators from 2011 onwards. This provides data from 2011 to 2013, on the number of patients surviving to hospital with return of spontaneous circulation (ROSC) (5,910 in 2011, 7,662 in 2012 and 8,033 in 2013).[12] Comparison of these data with MINAP data would suggest that MINAP captures approximately one third of resuscitated cardiac arrest patients and admitted to hospital. Interestingly, the number of resuscitated cardiac arrests admitted to hospital increased yearly according to Ambulance Service data. Our study also demonstrated an increase in the number of OHCA patients diagnosed and treated as ACS over the 5-year period. This could, in part, reflect a shift in post cardiac arrest management, with a greater percentage of patients admitted and surviving to hospital with OHCA who are investigated for and treated as ACS. However, this could also be attributable to improved case ascertainment in both pre-hospital and hospital-based audit systems.

Of patients identified in-hospital with a discharge diagnosis of ACS who presented with OHCA, the proportion of OHCA patients presenting with VT/VF per year within the in-hospital ACS cohort, remained unchanged. Comparison of these data with Ambulance Service National Quality Indicators demonstrate a similar picture, with the proportion of resuscitated cardiac arrests delivered to hospital with a presenting rhythm of VT/VF also remaining unchanged. This is despite the overall decrease in the observed incidence of VT/VF arrest out-of-hospital. This could be explained by pre-hospital factors, which include the decision by the ambulance crews to perform resuscitation and a more favourable outcome in this cohort, thus patients surviving to hospital with ROSC. It could also partially be explained by selection bias whereby a cardiac arrest with presenting rhythm of VT/VF is thought more likely to be ischemic in origin, and thus more likely to be treated and diagnosed with ACS, and thus entered into the MINAP database.

Over the 5-year period, distribution of baseline characteristics of the OHCA patients captured within the MINAP registry and therefore diagnosed with ACS broadened to include patients without traditional risk factors for coronary disease. This and the observed increase in the proportion of OHCA patients receiving coronary intervention could reflect a more pro-active approach both in England and internationally to post-arrest care during this period, with increased recognition and emphasis placed on the benefits of specialist cardiac care to manage ensuing cardiovascular dysfunction and treatment of the potential underlying cause through reperfusion. [13] This is in addition to the national increase in the use of PCI as the preferred reperfusion strategy.[14]

This study identified well-established predictors of survival and good neurological outcome in OHCA including VT/VF as the presenting rhythm. This has been shown in numerous observational studies.[6,15,16] Our study also showed that CA+PCI was associated with reduced in-hospital mortality following OHCA in patients with STE. CA+PCI was also associated with good neurological outcome and improved long-term survival. However, this study also showed that predictors of good outcome were synonymous with the selection criteria for patients undergoing CA±PCI, suggesting a degree of selection bias for coronary angiography towards patients believed to have characteristics associated with a more favorable outcome.

Over the 5-year period, in-hospital mortality increased in the OHCA cohort of ACS patients. However, the overall in-hospital mortality of those presenting with OHCA in the MINAP registry was shown to be much lower than the Ambulance Service National Quality Indicators would suggest, which is indicative of the selective nature of the data, with MINAP only capturing a proportion of all resuscitated cardiac arrests admitted to hospital. In OHCA patients who underwent CA+PCI, there was a slight but significant increase in in-hospital mortality, despite an increase in CA±PCI. This likely reflects a broadening of selection criteria for CAPCI extending to higher risk patients.

The observational nature of these data makes it impossible to derive conclusions about causality. The data for CA±PCI in the non-STE OHCA cohort are conflicting. Although non-STE patients in this study appeared to fare better with CA±PCI, they remain an extremely heterogeneous cohort, with multiple possible causes for arrest including non-cardiac causes, chronic coronary artery disease and scar-induced arrhythmia. The non-STE patients in the MINAP registry were a select group, with a confirmed diagnosis of ACS, entered into the database retrospectively, thus these findings cannot be transferable to all non-STE patients. However, these data would suggest that regardless of post-resuscitation ECG findings, patients with ACS as the cause of OHCA could benefit from CA±PCI. In the absence of STE following cardiac arrest, the ECG is less reliable in guiding diagnosis and a focus is placed on hemodynamic status and possible preceding symptoms prior to arrest. Recently published ESC guidelines recommend rule out of non-coronary causes prior to coronary angiography.[8] In the absence of convincing randomized data we are yet to determine the best post-arrest strategy for these patients. Further investigation in the form of a randomized trial of routine invasive angiography and revascularization, where appropriate following OHCA is necessary. The key factor here is to identify which patients benefit from an early invasive strategy. The coordination of this however, is complex, and close interaction is necessary pre-hospital between centers and emergency services and internally between the emergency department, Cardiologists, and the critical care unit. Several planned randomized control trials including Early Coronary Angiography Versus Delayed Coronary Angiography NCT02387398 and A Randomized tRial of Expedited transfer to a cardiac arrest center for non-ST elevation out of hospital cardiac arrest; ISRCTN 96585404 will address the optimal post-arrest pathway for these patients and if coronary angiography should be routinely performed in all patients with resuscitated arrest of presumed cardiac cause.[17]

Limitations

There are a number of limitations in this study that are inherent to retrospective database analysis that preclude conclusions with regard to causality. There was a large proportion of missing data, analyses of individuals with only full datasets can introduce bias thus multiple imputation analysis was performed. Multiple imputation works on the assumption that data are missing at random. Despite consistency in results in comparison with complete case analysis, and inclusion of a large number of variables in the MI model, we cannot confirm if the systematic differences between the missing values and the observed values can be explained by differences in observed data thus may be subject to bias. Therefore the results of this study must be considered hypothesis generating, thus supporting the need for a randomized controlled trial in this cohort.

The MINAP database only captures patients with a discharge diagnosis of ACS, which is at most one third of resuscitated cardiac arrests admitted to hospital, thus conclusions are not transferrable to the entire OHCA population. Furthermore, we cannot compare outcomes between patients with OHCA of presumed cardiac cause who received acute cardiac care and those who did not. Due to the lack of randomized data, selection for coronary intervention is subjective and we therefore cannot account for why individual patients were or were not chosen for this management strategy. This study did not include differentiation of outcome by centre; this would have been informative and could be predictive of outcome and also of missing values.

Conclusions

In this MINAP registry there was an increase in the proportion of OHCA cases treated as ACS over the 5-year period. The rate of CA+PCI increased and was associated with improved survival compared to cohorts not selected for this management strategy; however, as selection criteria broadened to include patients with additional comorbidities, outcomes declined. The future challenges are to identify those patients who will benefit from such a strategy. These data support the need for a randomized controlled trial in this patient cohort.

References

1. Perkins GD, Lockey AS, de Belder MA, Moore F, Weissberg P, Gray H, Community Resuscitation Group. National initiatives to improve outcomes from out-of-hospital cardiac arrest in England. *Emerg Med J*. 2016;33:448–451.

2. Writing Group Members, Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, Das SR, de Ferranti S, Després J-P, Fullerton HJ, Howard VJ, Huffman MD, Isasi CR, Jiménez MC, Judd SE, Kissela BM, Lichtman JH, Lisabeth LD, Liu S, Mackey RH, Magid DJ, McGuire DK, Mohler ER, Moy CS, Muntner P, Mussolino ME, Nasir K, Neumar RW, Nichol G,

Palaniappan L, Pandey DK, Reeves MJ, Rodriguez CJ, Rosamond W, Sorlie PD, Stein J, Towfighi A, Turan TN, Virani SS, Woo D, Yeh RW, Turner MB, American Heart Association Statistics Committee, Stroke Statistics Subcommittee. Heart Disease and Stroke Statistics-2016 Update: A Report From the American Heart Association. *Circulation*. 2016;133:e38–360.

3. Bobrow BJ, Spaite DW, Berg RA, Stolz U, Sanders AB, Kern KB, Vadeboncoeur TF, Clark LL, Gallagher JV, Stapczynski JS, LoVecchio F, Mullins TJ, Humble WO, Ewy GA. Chest compression-only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. *JAMA : the journal of the American Medical Association*. 2010;304:1447–1454.

4. Lick CJ, Aufderheide TP, Niskanen RA, Steinkamp JE, Davis SP, Nygaard SD, Bemenderfer KK, Gonzales L, Kalla JA, Wald SK, Gillquist DL, Sayre MR, Osaki Holm SY, Oski Holm SY, Oakes DA, Provo TA, Racht EM, Olsen JD, Yannopoulos D, Lurie KG. Take Heart America: A comprehensive, community-wide, systems-based approach to the treatment of cardiac arrest. *Critical care medicine*. 2011;39:26–33.

5. Kern KB. Optimal treatment of patients surviving out-of-hospital cardiac arrest. *JACC: Cardiovascular Interventions*. 2012;5:597–605.

6. Spaulding CM, Joly LM, Monchi M, Weber SN, Dhainaut J-FF, Carli P, Rosenberg A, Weber SN, Dhainaut J-FF. Immediate coronary angiography in survivors of out-of-hospital cardiac arrest. *The New England journal of medicine*. 1997;336:1629–1633.

7. Levine GN, Bates ER, Blankenship JC, Bailey SR, Bittl JA, Cercek B, Chambers CE, Ellis SG, Guyton RA, Hollenberg SM, Khot UN, Lange RA, Mauri L, Mehran R, Moussa ID, Mukherjee D, Ting HH, O'Gara PT, Kushner FG, Brindis RG, Casey DE, Chung MK, de Lemos JA, Diercks DB, Fang JC, Franklin BA, Granger CB, Krumholz HM, Linderbaum JA, Morrow DA, Newby LK, Ornato JP, Ou N, Radford MJ, Tamis-Holland JE, Tommaso CL, Tracy CM, Woo YJ, Zhao DX. 2015 ACC/AHA/SCAI Focused Update on Primary Percutaneous Coronary Intervention for Patients With ST-Elevation Myocardial Infarction: An Update of the 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention and the 2013 ACCF/AHA Guideline for the Management of ST-Elevation Myocardial Infarction: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Society for Cardiovascular Angiography and Interventions. *Circulation*. 2015;133:CIR.0000000000000336–1147.

8. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, Caforio ALP, Crea F, Goudevenos JA, Halvorsen S, Hindricks G, Kastrati A, Lenzen MJ, Prescott E, Roffi M, Valgimigli M, Varenhorst C, Vranckx P, Widimsky P. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). *European heart journal*. 2017;

9. Herrett E, Smeeth L, Walker L, Weston C. The Myocardial Ischaemia National Audit Project (MINAP). *Heart (British Cardiac Society)*. 2010;96:1264–1267.

10. Alahmar AE, Nelson CP, Snell KIE, Yuyun MF, Musameh MD, Timmis A, Birkhead JS, Chugh SS, Thompson JR, Squire IB, Samani NJ. Resuscitated cardiac arrest and prognosis following myocardial infarction. *Heart*. 2014;100:1125–1132.

11. Sterne JAC, White IR, Carlin JB, Spratt M, Royston P, Kenward MG, Wood AM, Carpenter JR. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ (Clinical research ed)*. 2009;338:b2393–b2393.

12. Perkins GD, Cooke MW. Variability in cardiac arrest survival: the NHS Ambulance Service

Quality Indicators. *Emerg Med J*. 2012;29:3–5.

13. Peberdy MA, Callaway CW, Neumar RW, Geocadin RG, Zimmerman JL, Donnino M, Gabrielli A, Silvers SM, Zaritsky AL, Merchant R, Vanden Hoek TL, Kronick SL. Part 9: post-cardiac arrest care: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2010;122:S768–86.

14. Weston C, Gavalova L, Whittaker T, van Leeven R. Myocardial Ischaemia National Audit Project. How the NHS cares for patients with heart attack. Annual Public Report April 2013–March 2014. … . ucl. ac. uk/nicor/audits/minap/ …; 2014.

15. Dumas F, Cariou A, Manzo-Silberman S, Grimaldi D, Vivien BIT, Rosencher J, Empana J-P, Carli P, Mira J-P, Jouven X, Spaulding C. Immediate percutaneous coronary intervention is associated with better survival after out-of-hospital cardiac arrest: insights from the PROCAT (Parisian Region Out of hospital Cardiac ArresT) registry. *Circulation: Cardiovascular Interventions*. 2010;3:200–207.

16. Dumas F, Bougouin W, Geri G, Lamhaut L, Rosencher J, Pène F, Chiche J-D, Varenne O, Carli P, Jouven X, Mira J-P, Spaulding C, Cariou A. Emergency Percutaneous Coronary Intervention in Post-Cardiac Arrest Patients Without ST-Segment Elevation Pattern: Insights From the PROCAT II Registry. *JACC Cardiovasc Interv*. 2016;9:1011–1018.

17. Patterson T, Perkins GD, Joseph J, Wilson K, Van Dyck L, Robertson S, Nguyen H, McConkey H, Whitbread M, Fothergill R, Nevett J, Dalby M, Rakhit R, MacCarthy P, Perera D, Nolan JP, Redwood SR. A Randomised tRial of Expedited transfer to a cardiac arrest centre for non-ST elevation ventricular fibrillation out-of-hospital cardiac arrest: The ARREST pilot randomised trial. *Resuscitation*. 2017;0.

Figures

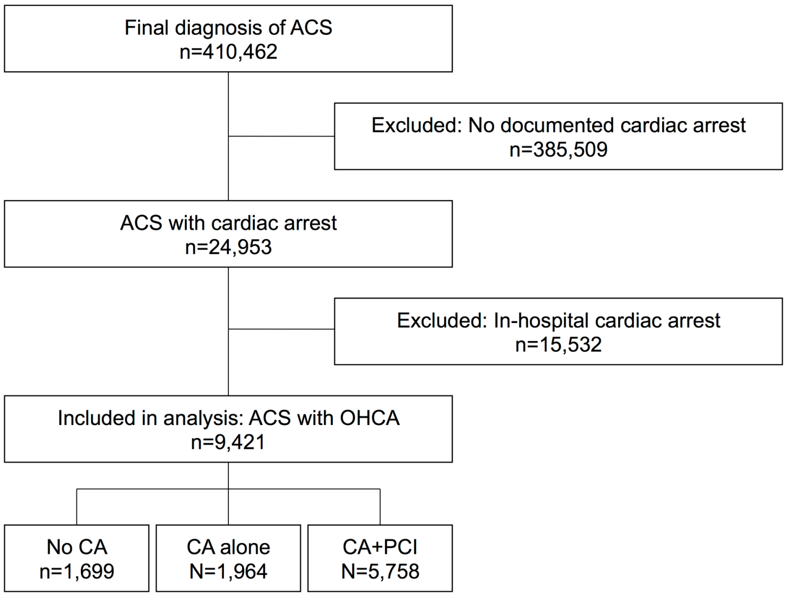

Figure 1. Patient flow diagram and study design. Data were extracted for the time period January 2009 to July 2013. Patients were identified in-hospital. All patients with a final discharge diagnosis of acute coronary syndrome complicated by out-of-hospital cardiac arrest were included in the final analysis. Abbreviations: ACS acute coronary syndrome, OHCA out-of-hospital cardiac arrest, CA coronary angiogram, PCI percutaneous coronary intervention

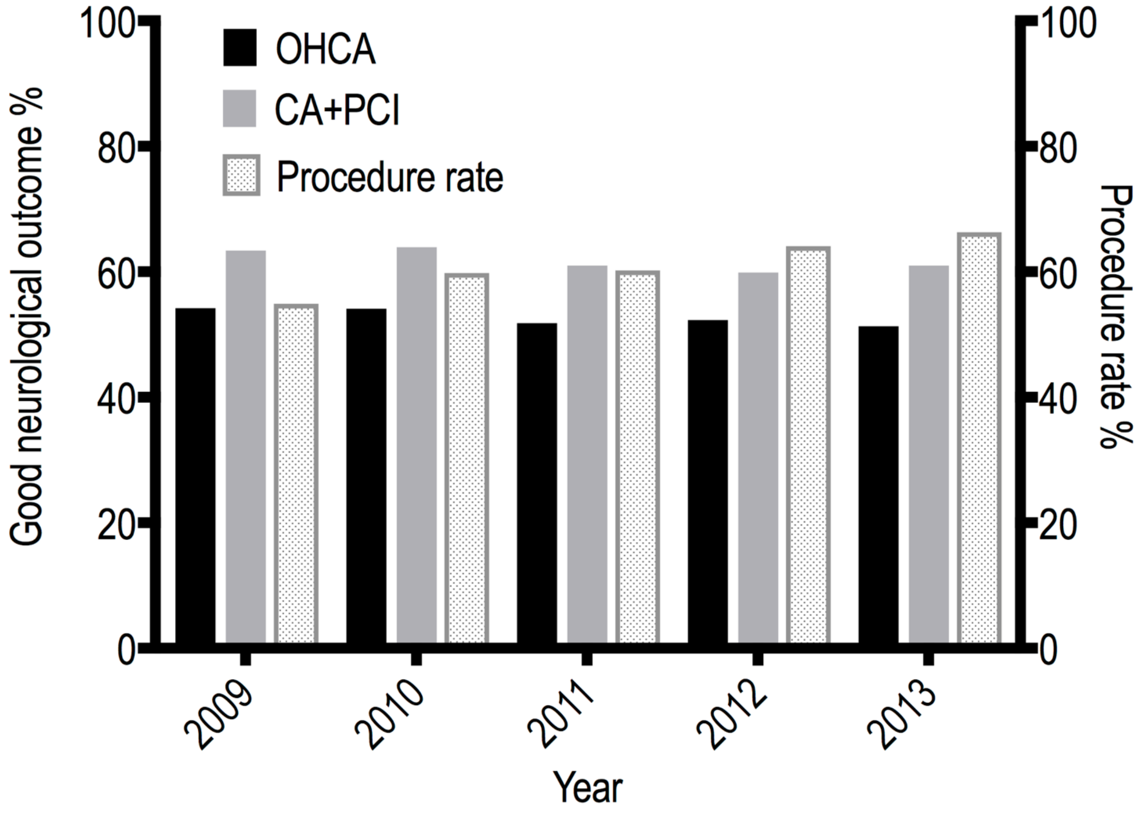

Figure 2 The temporal trends in good neurological outcome of the overall OHCA cohort (black) and the cohort of coronary angiogram + percutaneous coronary intervention (PCI) (gray), trends in procedural rate of coronary angiogram + PCI is also shown (pattern).

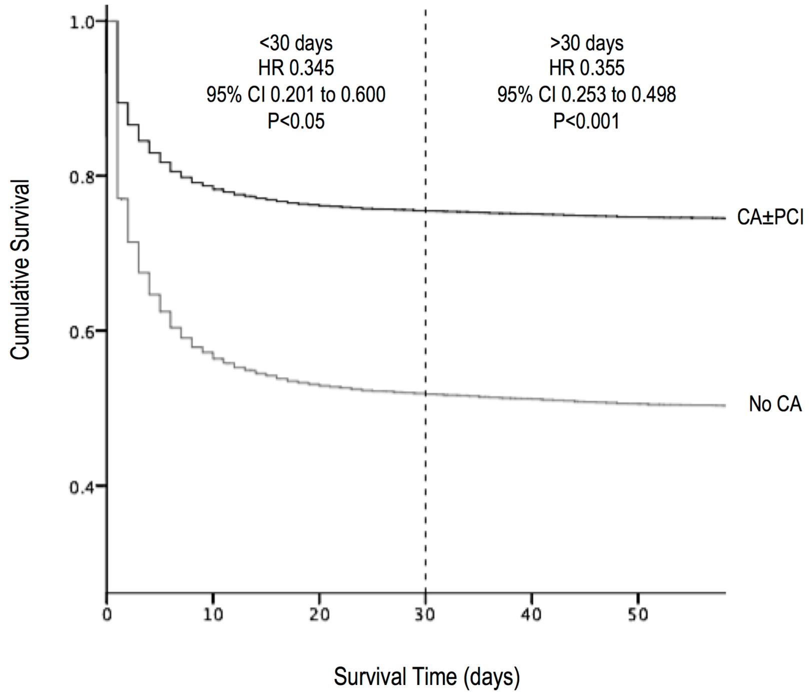

Figure 3 Survival curves according to coronary angiogram ± PCI (black) and no coronary angiogram (gray). Cox-proportional hazards model was used to calculate time-varying hazard ratios. Survival represents life status, which includes survival both in-hospital and following discharge. Abbreviations: CA coronary angiogram, PCI percutaneous coronary intervention.

Tables

Baseline Characteristic	Year of Admission										
	2009		2010		2011		2012		2013†		P value
Age over 75	391/1595	24.5%	422/1835	23.0%	524/2142	24.5%	625/2515	24.9%	304/1334	22.8%	0.880
Sex (Male)	1193/1595	74.8%	1369/1835	74.6%	1596/2142	74.5%	1952/2515	77.6%	1037/1334	77.7%	<0.05*
ST-Elevation	999/1595	62.6%	1205/1835	65.7%	1352/2142	63.1%	1696/2515	67.4%	872/1334	65.4%	<0.05*
Previous AMI	348/1595	21.8%	364/1835	19.8%	436/2142	20.4%	483/2515	19.2%	232/1334	17.4%	<0.05*
Previous Angina	326/1595	20.4%	365/1835	19.9%	392/2142	18.3%	394/2515	15.7%	211/1334	15.8%	<0.001*
Hypertension	661/1595	41.4%	768/1835	41.9%	891/2142	41.6%	1046/2515	41.6%	542/1334	40.6%	0.820
Hypercholesterolemia	459/1595	28.8%	531/1835	28.9%	584/2142	27.3%	670/2515	26.6%	333/1334	25.0%	<0.05*
Peripheral Vascular Disease	46/1595	2.9%	59/1835	3.2%	97/2142	4.5%	94/2515	3.7%	51/1334	3.8%	0.180
Cerebrovascular Disease	111/1595	7.0%	129/1835	7.0%	152/2142	7.1%	208/2515	8.3%	86/1334	6.4%	0.729
Chronic Renal Failure	65/1595	4.1%	74/1835	4.0%	87/2142	4.1%	114/2515	4.5%	62/1334	4.6%	0.638
Heart Failure	92/1595	5.8%	92/1835	5.0%	122/2142	5.7%	144/2515	5.7%	66/1334	4.9%	0.756
Smoker	1028/1595	64.5%	1160/1835	63.2%	1350/2142	63.0%	1563/2515	62.1%	809/1334	60.6%	<0.05*
Diabetes	188/1595	11.8%	260/1835	14.2%	306/2142	14.3%	382/2515	15.2%	172/1334	12.9%	0.234
Previous PCI	134/1595	8.4%	143/1835	7.8%	161/2142	7.5%	201/2515	8.0%	99/1334	7.4%	0.339
Previous CABG	116/1595	7.3%	103/1835	5.6%	112/2142	5.2%	140/2515	5.6%	73/1334	5.5%	<0.05*
Family History	407/1595	25.5%	460/1835	25.1%	548/2142	25.6%	544/2515	21.6%	308/1334	23.1%	<0.001*
Pulseless VT/VF	1418/1595	88.9%	1656/1835	90.2%	1861/2142	86.9%	2218/2515	88.2%	1159/1334	86.9%	0.061

Table 1 Annual trends in baseline characteristics, including the cardiovascular risk factors, of the 9,421 patients with troponin positive acute coronary syndrome (ACS) presenting as out-of-hospital cardiac arrest (OHCA) over the 5-year period. Data are displayed per year, as counts n/N and percentages (%), where n is the number of patients documented as having the presence of a baseline characteristic, N is the total number of ACS patients in that year documented as OHCA and % is the proportion (2009 N=1595, 2010 N=1835, 2011 N=2142, 2012 N=2515, 2013 N=1334). * Indicates unadjusted $P<0.05$. †Numerical data only available from January to July 2013. Abbreviations in order of appearance: AMI acute myocardial infarction, PCI percutaneous coronary intervention, CABG coronary artery bypass graft surgery, VT/VF pulseless ventricular tachycardia/ventricular fibrillation.

Baseline Characteristic (CA±PCI)	Year of Admission										
	2009		2010		2011		2012		2013†		P value
Age over 75	266/1227	18.4%	301/1468	20.5%	381/1738	21.9%	472/2138	22.0%	239/1151	20.8%	0.724
Sex (Male)	933/1227	76.0%	1124/1468	76.6%	1323/1738	76.1%	1692/2138	79.1%	910/1151	79.1%	<0.05*
ST-Elevation	832/1227	67.8%	1041/1468	71.0%	1191/1738	68.5%	1539/2138	72.0%	797/1151	69.2%	0.355
Previous AMI	242/1227	19.7%	262/1468	17.9%	328/1738	18.9%	377/2138	17.6%	184/1151	16.0%	<0.05*
Previous Angina	228/1227	18.6%	259/1468	17.7%	295/1738	17.0%	304/2138	14.2%	169/1151	14.7%	<0.05*
Hypertension	503/1227	41.0%	621/1468	42.3%	710/1738	40.9%	877/2138	41.0%	458/1151	39.8%	0.576
Hypercholesterolemia	360/1227	29.3%	433/1468	29.5%	483/1738	27.8%	580/2138	27.1%	289/1151	25.1%	<0.05*
Peripheral Vascular Disease	32/1227	2.6%	44/1468	3.0%	74/1738	4.3%	79/2138	3.7%	42/1151	3.6%	0.125
Cerebrovascular Disease	74/1227	6.0%	88/1468	6.0%	106/1738	6.1%	159/2138	7.4%	63/1151	5.5%	0.806
Chronic Renal Failure	40/1227	3.3%	46/1468	3.1%	58/1738	3.3%	80/2138	3.7%	45/1151	3.9%	0.593
Heart Failure	61/1227	5.0%	60/1468	4.1%	89/1738	5.1%	110/2138	5.1%	49/1151	4.3%	0.602
Smoker	803/1227	65.4%	946/1468	64.5%	1117/1738	64.3%	1353/2138	63.3%	709/1151	61.6%	<0.05*
Diabetes	136/1227	11.1%	201/1468	13.7%	247/1738	14.2%	323/2138	15.1%	137/1151	11.9%	0.124
Previous PCI	108/1227	9.1%	120/1468	8.2%	134/1738	7.7%	175/2138	8.2%	84/1151	7.3%	0.222
Previous CABG	74/1227	8.8%	69/1468	4.7%	81/1738	4.7%	98/2138	4.6%	54/1151	4.7%	0.170
Family History	341/1227	27.8%	398/1468	27.1%	483/1738	27.8%	485/2138	22.7%	284/1151	24.7%	<0.001*
VT/VF	1119/1227	91.2%	1350/1468	92.0%	1552/1738	89.3%	1940/2138	90.7%	1030/1151	89.5%	<0.05*

Table 2. Annual trends in the baseline characteristics of ACS patients presenting with OHCA that were selected to undergo any coronary procedure (coronary angiography (CA) ± PCI) over the 5-year period (7,722/9,421) comprised of CA alone (1964) and CA+PCI (5758). Data are described as counts (n/N) and percentages (%); where n is the number of patients with a characteristic, and N is the total number of patients in that year who underwent CA±PCI (2009 N=1227, 2010 N=1468, 2011 N=1738, 2012 N=2138, 2013 N=1151). * Indicates unadjusted $P<0.05$. †Numerical data only available from January to July 2013. Abbreviations in order of appearance: AMI acute myocardial infarction, PCI percutaneous coronary intervention, CABG coronary artery bypass graft surgery, VT/VF pulseless ventricular tachycardia/ventricular fibrillation.

Baseline Characteristic	Procedure Specific Data						
	No CA (1)		CA alone (2)		CA+PCI (3)		P Value
Age over 75	607/1699	35.7%	600/1964	30.5%	1059/5758	18.4%	<0.001*
Sex (Male)	724/1699	42.6%	531/1964	27.0%	4868/5758	84.5%	<0.001*
ST-Elevation	350/1699	20.6%	535/1964	27.2%	5274/5758	91.6%	<0.001*
Previous AMI	470/1699	27.7%	607/1964	30.9%	787/5758	13.7%	<0.001*
Previous Angina	435/1699	25.6%	500/1964	25.5%	754/5758	13.1%	<0.001*
Hypertension	738/1699	43.4%	955/1964	48.6%	2214/5758	38.5%	<0.001*
Hypercholesterolemia	433/1699	25.5%	564/1964	28.7%	1580/5758	27.4%	<0.001*
Peripheral Vascular Disease	76/1699	4.5%	94/1964	4.8%	177/5758	3.1%	<0.05*
Cerebrovascular Disease	195/1699	11.5%	177/1964	9.0%	314/5758	5.5%	<0.001*
Chronic Renal Failure	135/1699	7.9%	139/1964	7.0%	130/5758	2.3%	<0.001*
Heart Failure	148/1699	8.7%	208/1964	10.6%	160/5758	2.8%	<0.001*
Smoker	982/1699	57.8%	1022/1964	52.0%	3906/5758	67.8%	<0.001*
Diabetes	264/1699	15.5%	396/1964	20.2%	649/5758	11.3%	<0.001*
Previous PCI	116/1699	6.8%	184/1964	9.4%	437/5758	7.6%	<0.001*
Previous CABG	168/1699	9.9%	223/1964	11.4%	153/5758	2.7%	<0.001*
Family History	278/1699	16.4%	355/1964	18.1%	1636/5758	28.4%	<0.001*
VT/VF	1322/1699	77.8%	1638/1964	83.4%	5353/5758	93.0%	<0.001*

Table 3 A comparison of the baseline characteristics of all patients selected to undergo a coronary procedure with those who were not, from the 5-year cohort of ACS patients presenting with OHCA (9,421). This is subdivided into groups: (1) no coronary angiogram (CA) (1,191/9,421); (2) coronary angiogram (CA) only (1,785/9,421); and (3) coronary angiogram + percutaneous coronary intervention (CA+PCI) (6,445/9,421). For clarification see Figure 1. Data are displayed as counts n/N and percentages (%), where n is the number of patients documented as having the presence of a baseline characteristic, N is the total number of patients in each cohort and % is the proportion, * indicates unadjusted P<0.05. Abbreviations: VT/VF pulseless ventricular tachycardia/ventricular fibrillation, CABG coronary artery bypass graft surgery, PCI percutaneous coronary intervention.

Variable	Adjusted Odds Ratio	95% Confidence Interval	P Value
CA±PCI			
STE	2.51	1.89 to 5.31	<0.05
Male sex	1.53	1.22 to 1.90	<0.05
Cerebrovascular Disease	0.70	0.544 to 0.893	<0.05
Previous coronary artery bypass graft	0.70	0.523 to 0.924	<0.05
CA+PCI			
VT/VF	2.16	1.29 to 3.63	<0.05
STE	8.34	7.00 to 9.94	<0.05
Previous PCI	1.88	1.24 to 2.85	<0.05
Hypercholesterolemia	1.31	1.04 to 1.66	<0.05
Smoking history	1.45	1.20 to 1.76	<0.05
Previous coronary artery bypass graft	0.46	0.35 to 0.61	<0.05
Heart failure	0.69	0.49 to 0.98	<0.05
Previous AMI	0.55	0.44 to 0.69	<0.05

Table 4. Multivariable logistic regression analysis demonstrating significant associations between categorical covariates and (i) CA±PCI and (ii) CA+PCI (n=9,421). Abbreviations: STE ST-elevation on post resuscitation ECG, PCI percutaneous coronary intervention, VT/VF pulseless ventricular tachycardia/ventricular fibrillation, AMI acute myocardial infarction.

Variable	Adjusted Odds Ratio	95% Confidence Interval	P Value
Predictors of in-hospital mortality			
VT/VF	0.15	0.13 to 0.18	<0.001
Family History	0.39	0.31 to 0.49	<0.001
CA+PCI	0.62	0.40 to 0.95	<0.05
Hypercholesterolemia	0.69	0.59 to 0.81	<0.05
Smoking history	0.73	0.63 to 0.85	<0.001
Male sex	0.79	0.70 to 0.89	<0.001
Chronic renal failure	1.40	1.04 to 1.89	<0.05
Cerebrovascular disease	1.54	1.25 to 1.90	<0.001
Age over 75	1.59	1.40 to 1.81	<0.001
Heart failure	1.59	1.25 to 2.02	<0.001
Peripheral Vascular disease	1.75	1.31 to 2.33	<0.001
Diabetes	1.98	1.65 to 2.37	<0.001

Table 5. Multivariable logistic regression analysis demonstrating significant associations between categorical covariates and in-hospital mortality (n=9,421). Abbreviations: VT/VF pulseless ventricular tachycardia/ventricular fibrillation, AMI acute myocardial infarction.